

Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)



ABSTRACT

At the Kennedy Space Center (KSC) the Launch Services Program is leading an effort to conduct an experiment aboard the International Space Station (ISS) to validate computational fluid dynamics (CFD) models. As spacecraft missions get longer and more ambitious, it becomes increasingly important that we fully understand the location and movement of liquids inside the propellant tanks of these vehicles. It is essential to understand how the movement of the liquid propellant will affect the trajectory of the vehicle. Current CFD models should predict these dynamics, but because test data is lacking, the accuracy of the models is not well understood. The slosh experiment aboard the ISS sets out to acquire this type of data.

ANTICIPATED BENEFITS

To NASA funded missions:

Currently funded NASA missions will be able to design more efficient trajectory profiles which will allow them to increase mission lifetimes and decrease risk. Validated models from this experiment will be used to predict the motion of liquid propellants inside the tanks of future space missions increasing safety, performance, and reliability.

To NASA unfunded & planned missions:

Powerful rockets use liquid fuel to bring satellites into orbit, and are subjected to varying forces as they are propelled forward. But computer simulations may not accurately represent how liquids behave in low-gravity conditions, causing safety concerns. The Slosh experiments improve these models, and thereby improve rocket safety, by measuring how liquids move around inside a container when external forces are applied to it. This simulates how rocket fuels swirl around inside their tanks while a rocket moves through space. The data from this experiment can then be used to check computer simulations on how rockets work, ultimately leading to rockets and spacecraft

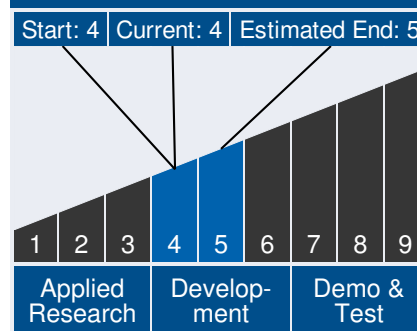


Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR)

Table of Contents

Abstract	1
Anticipated Benefits	1
Technology Maturity	1
Detailed Description	2
Management Team	2
Technology Areas	2
U.S. Work Locations and Key Partners	4
Image Gallery	5
Details for Technology 1	5

Technology Maturity



Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)



that are more reliable, safer and cost effective.

To the commercial space industry:

Data from this experiment will allow for greater confidence in the performance of future missions, as well as improve safety for both manned and unmanned missions. The commercial space industry and any other government agencies will be able to use the data collected and the information learned from the analysis of that data which will impact the ability to improve the performance of rockets and spacecraft.

To the nation:

Many satellites launch on rockets powered by liquid fuel, and improved understanding of these propellants could enhance efficiency, potentially lowering costs for industry and taxpayer-funded satellite launches. More generally, the investigation's results provide new data for fluid dynamics simulations. This investigation is being shared with middle school and high school students and teachers in a planned outreach program to continue to inspire the next generation of scientists and engineers. Students involved in the SPHERES experiments actively participate in hands on activities generating interest in science, technology, engineering and math careers.

DETAILED DESCRIPTION

The Synchronized Position, Hold, Engage, Reorient, Experimental Satellites – VERTIGO (SPHERES- VERTIGO) developed by the Massachusetts Institute of Technology (MIT)—are free-floating, soccer-ball-sized robots with their own propulsion and power. They are used aboard the ISS to study formation flight and other control system algorithms. For this experiment, these same SPHERES will be programmed with thruster firings that will emulate common maneuvers carried out by launch vehicles and spacecraft. This motion will impart energy to the fluid inside the experiment, which will measure its effects. The ISS provides the perfect

Management Team

Program Executive:

- Ryan Stephan

Program Manager:

- Stephen Gaddis

Principal Investigator:

- Paul Schallhorn

Technology Areas

Primary Technology Area:

Launch Propulsion Systems (TA 1)

Secondary Technology Area:

In-Space Propulsion Technologies (TA 2)

Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)



environment to conduct liquid behavior studies in microgravity. This investigation is planned to collect valuable data on how liquids move around inside of a container when external forces are applied to that container – this simulates how rocket fuels move around inside their tanks when motor thrusts are used to push the rocket through space. The slosh experiment takes advantage of hardware already on the ISS. The primary slosh experiment component is a clear, pill-shaped Lexan tank in the middle of the assembly. This tank is shrouded by a tan box designed to prevent the ISS ambient lights from interfering with the cameras. Also in the middle, is the center hub made of aluminum. This center hub has two arms to hold two high-resolution cameras. These cameras will collect video of the fluid inside the tank. The center hub assembly is connected to a larger frame, which connects to the two SPHERES units through a clamp system. VERTIGO computers attached to the SPHERES units will collect the data from the cameras and the onboard inertial measurement units. These computers are already on the ISS and will be used by the slosh experiment as storage and power for the cameras and accelerometers.

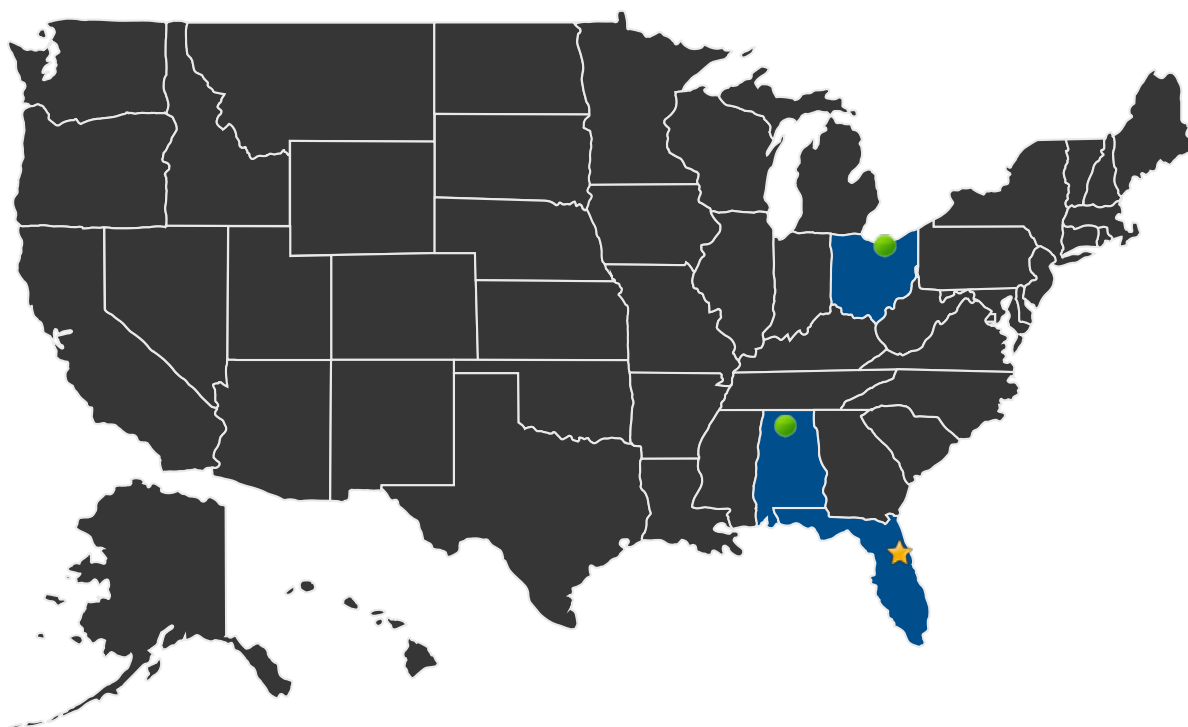
Completed Project (2011 - 2014)

Dedicated Slosch Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)



U.S. WORK LOCATIONS AND KEY PARTNERS



■ U.S. States With Work

★ **Lead Center:**
Kennedy Space Center

● **Supporting Centers:**

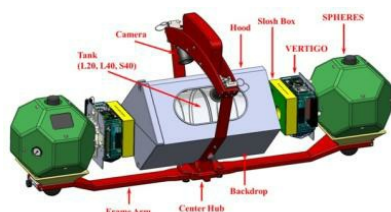
- Glenn Research Center
- Marshall Space Flight Center

Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

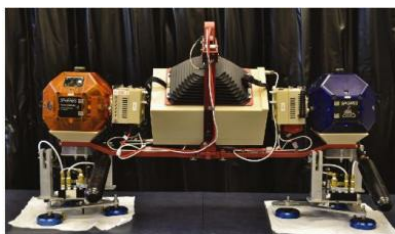
Game Changing Development Program | Space Technology Mission Directorate (STMD)



IMAGE GALLERY



Dedicated Slosh Dynamics Experiment on ISS



Fully assembled slosh experiment (top); slosh experiment components (bottom)

DETAILS FOR TECHNOLOGY 1

Technology Title

Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR)

Technology Description

This technology is categorized as a hardware system for other applications

The SPHERES Slosh Experiment will be equipped with a clear partially filled liquid tank, video cameras and a data acquisition system. This free floating experiment will autonomously perform typical upper stage vehicle maneuvers within the ISS. The liquid response will be photographed, measured, and used to validate current Computational Fluid Dynamics (CFD) models.

These validated models will then be used to predict the motion of liquid propellants inside the tanks of future space missions increasing safety, performance, and reliability.

Dedicated Slosh Dynamics Experiment on ISS using SPHERES (Advanced Space Operations in CR) Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)



Capabilities Provided

This experiment will be capable of taking video and inertial measurement data for a free floating experiment aboard the ISS. The experiment is modular and allows for future expansion, different tanks, and alternate configurations. In addition to acquiring long duration, low-gravity slosh data for calibration of detailed CFD models of coupled fluid-vehicle behavior in order to reduce mission risk and uncertainty levels.

Potential Applications

Initial testing aboard the ISS will replicate three common upper-stage vehicle maneuvers and is predicted to record roughly 2 hours of test data for analysis back on Earth, where the data will be stored in a comprehensive database of slosh testing. The test data will be made available to other slosh researchers through the Electronic Slosh Data Catalog maintained by the Launch Services Program. The experiment will be left aboard the ISS for future testing, such as investigating the effects of different-shaped tanks, various propellant management devices, fluids with varying viscosity, and other maneuvers.

The data gathered by this experiment will be invaluable and used to better quantify the accuracy of current CFD models. Once validated, these models will allow for greater confidence in the performance of future missions, as well as improve safety for both manned and unmanned missions.

Performance Metrics

Metric	Unit	Quantity
width	1	feet
height	1	feet
length	3.2	feet